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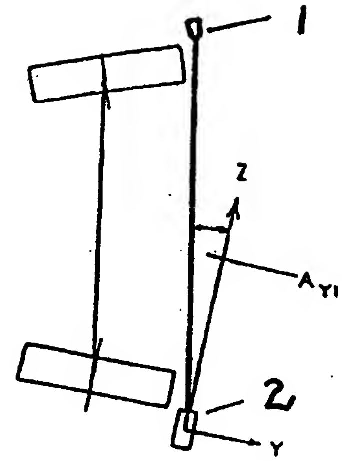
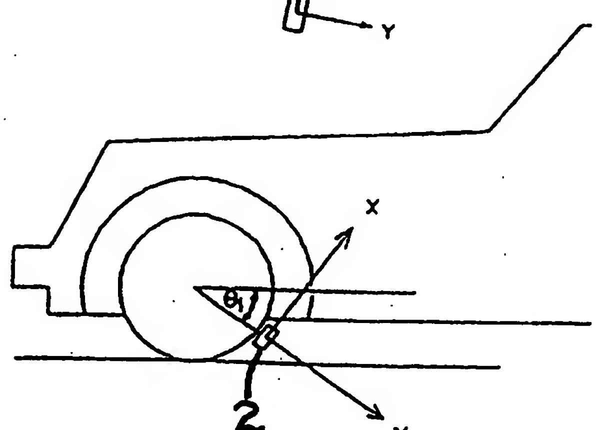
(54) Title: WHEEL ALIGNMENT SYSTEM

(57) Abstract

The determination of toe and camber angles of one of a pair of wheels consists of selecting a first point (2) related to a first wheel, making measurements from which the angular displacement of a plane through the first point and the axis of the first wheel to a plane through the wheels centre can be determined, selecting an equivalent second point (1) related to the second wheel and making measurements from which the angular displacements of a line between the selected points in orthogonal planes through the first point (2) can be calculated, rotating the wheels and related selected points through similar angles, repeating the measurements and calculating therefrom the toe and camber angles of the first wheel.





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WHEEL ALIGNMENT SYSTEM

This invention relates to an apparatus and to a method for measuring and correcting the alignment of the road wheels of a vehicle.

BACKGROUND TO THE INVENTION

The correct alignment of the road wheels of a motor vehicle is of paramount importance in achieving optimum vehicle efficiency and tyre wear. If the axles of the wheels of a motor vehicle are not parallel while the vehicle is in motion, excessive tyre wear and increased rolling resistance will result. The alignment of the wheels of the motor vehicle is of particular importance in this regard as they usually steer and brake the vehicle.

Alignment parameters on the steering wheels of a vehicle which affect tyre wear and rolling resistance are camber angle and toe-in. The camber angle is the inclination from the vertical of the steerable wheels of an automobile, whilst toe-in is the degree to which the forward part of the front wheels of an automobile are closer together than the rear part, measured at hub height with the wheels in a normal "straight ahead" position of the steering gear of the vehicle.

Other parameters which are also important for correct performance of the suspension and steering of the motor vehicle are castor, steering axis inclination and toe-out on turn, although these parameters are not adjustable on all types of motor vehicles.

Castor is the inclination of the kingpin or its equivalent in automotive steering as viewed along the axis of the front wheels of a motor vehicle.

Four wheel alignment is required on some motor cars to ensure that the front and rear axles of a vehicle are parallel to one another and that the thrust line of the motor vehicle co-incides with the centre line.

On some modern cars both front and rear wheels are steerable and the alignment of the rear wheels on these vehicles is similar to that of their front wheels.

At present wheel alignment of motor vehicles is usually measured by means of sensors which are secured to the rims of the road wheels of the vehicle. These sensors generally measure absolute angles whilst the car is stationary on a level surface. It is well known that the accurate measurement of absolute angles is difficult and costly to achieve.

In prior art wheel alignment systems, measurements are made relative to a reference or zero value. The misalignment of the sensors relative to the reference or zero value causes measurement inaccuracies ("runout error"). Runout errors are eliminated by raising the vehicle and either mechanically or electronically correcting the runout error. When the vehicle is lowered, the suspension is unlikely to settle back to its normal operating, equilibrium position, contributing to further measurement inaccuracy.

OBJECT OF THE INVENTION

It is an object of the invention to provide an apparatus and a method for measuring the alignment parameters of the road wheels of a motor vehicle which will, substantially, alleviate the above-mentioned difficulties and disadvantages.

SUMMARY OF THE INVENTION

According to this invention there is provided a method for determining alignment parameters of one of a pair of wheels comprising selecting a first point related to a first wheel, making measurements from which the angular displacement of a plane through the first point and the axis of the first wheel to a plane through the wheel centre can be determined, selecting an equivalent second point related to the second wheel and making measurements from which the angular displacements of a line between the selected points in orthogonal planes through the first point can be calculated, rotating the wheels and related selected points through similar angles, repeating the measurements and calculating therefrom the toe and camber angles of the first wheel.

The invention further provides for the selected points to be chosen adjacent to the peripheries of the wheels and substantially parallel to the line joining the wheel centres, for the points to be selected to be below the horizontal plane of the wheel centre and the angle of rotation chosen to be greater than 180°, for similar measurements and calculations to be made for the second wheel and for the measurement and calculations for both wheels to be done simultaneously.

Still further features of this invention provide for the angular displacements of the plane through the first points to be θ_1 and θ_2 and the angular displacements of the line between the selected points and orthogonal planes through the first point to be A_{x1} and A_{x2} and A_{y1} and A_{y2} from which $A_x = (A_{x2} - A_{x1})$ and $A_y = (A_{y1} - A_{y2})$ are determined and the angular inclination of the wheel calculated bysimultaneous solution of the equations

$$X_c = \frac{A_x + X_t(\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

$$X_t = \frac{-A_y - X_c(\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

where X_t is the toe angle of the wheel and X_c is the camber of the wheel.

Yet further features of this invention provide for the measurements to be made of the angular displacement between the selected points in orthogonal planes through the point by means of transmitted electromagnetic radiation and a receiver that records the radiation transmitted in at least one dimension, for the radiation to be recorded in at least two different planes, for the radiation to be light radiation and for the planes to be orthogonally oriented to each other.

Still further features of this invention provide for the angular displacement of the plane through the first point and the axis of the first wheel to be measured by a gravitationally

operated instrument and for the gravitational displacement to be measured by accelerometers or inclinometers

A further aspect of this invention provides a method of determining the orientation relative to a chosen plane of a wheel axis of a wheeled vehicle positioned on a supporting plane comprising selecting a point relative to the axis of the wheel and a second point fixed relative to the vehicle, and set apart from the wheel axis but in a plane approximately parallel to the plane supporting the wheels, making measurements from which the angle between the line joining the two points and a reference line can be determined, rotating the wheel through a predetermined angle, repeating the measurements with respect to a second reference line of known variation to the first and calculating the angle of the wheel axis relative to the line joining the two points.

Further features of this aspect of the invention provide for the toe angle to be obtained by selecting the points such that the line between the points is parallel to the axis of the vehicle.

This aspect of the invention also provides for the method to be applied to the other of a pair of wheels and for the results of both sets of measurements to be used to calculate the thrust angle or the set back between the pair of wheels or the toe angle of the first wheel.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention is described below with reference to the accompanying diagramatic drawings in which:

Figs 1 and 2 show directional variations measured to calculate wheel camber and toe-in angles and

Figs 3 and 4 show directional variations measured to verify wheel toe angles and/or to determine the thrust angle of a pair of wheels.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig 1 a directional light beam transmitter (1), preferably in the form of an infra red light transmitting diode (LED) is attached to the rear side of the right front wheel near its circumference, so that the beam is propogated horizontally under the vehicle approximately parallel to the axle towards the left front wheel. This LED is imaged by a receiver (2) (details of which are given below) attached to the other wheel at approximately the height. An orthogonal set of axes XYZ is defined with respect to the receiver (2) which is at the origin of the axes. The angle A_{y1} between the LED image and the Z-axis of the receiver is measured in the Y - Z plane. In Fig 1 the angle A_{y1} is negative due to the toe-in of the left wheel. If the receiver (2) is attached to the wheel such that the Z-axis is precisely parallel to the wheel axle and both LED and receiver (2) are at axle height such that $\theta_1 = 0$ and the wheels are the same diameter then the angle A_{y1} is the toe angle of the left wheel. It is difficult to mount the receiver (2) precisely parallel to the axle, that is the zero runout error, and the wheels may not be the same diameter. These problems can be overcome by making a second set of measurements after moving the car such that the wheel rotates through 180°. With the steering wheel locked in the straight forward position the vehicle is rolled forward until the receiver (2) can image the LED on the front side of the wheel as shown in Fig 2, and the angle A_{y2} is measured. If the measurements of A_{y1} and A_{y2} are made at $\theta_1 = 0$ and $\theta_2 = 180°$ respectively then $(A_{y2} - A_{y1}) / 2$ is the toe angle of the left front wheel and the measurement is independent of the wheel diameters and. the angle (runout) at which the receiver is mounted.

Similarly the camber angle of the left front wheel can be determined from two measurements of the angle from the receiver (2) to the LED (1) in the X - Z plane: A_{x1} and A_{x2} .

On most vehicles it is not possible to make measurements at axle height as the body of the vehicle interferes, so the first measurement is made at $\theta_1 < 0$ and the second at $\theta_1 > 180°$. Hence the toe and camber measurements interact. In this case the angles $A_y = (A_{y2} - A_{y1})$ and $A_x = (A_{x2} - A_{x1})$ are given by:

$$A_x = X_c \ (\cos\theta_2 - \cos\theta_1) - X_t \ (\sin\theta_2 - \sin\theta_1)$$

$$A_y = -X_c(\sin\theta_2 - \sin\theta_1) - X_t(\cos\theta_2 - \cos\theta_1)$$

where X_t is the toe angle of the wheel defined as positive for toe in and X_c is the camber angle of the wheel defined as positive when the top of the wheel leans outwards.

From measurement of A_x and A_y toe and camber can be calculated as follows:

$$X_c = \frac{A_x + X_t(\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

$$X_t = \frac{-A_y - X_c(\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

These equations are solved simultaneously by a simple iterative technique. Note that A_x and A_y are each differences between two measurements made at any two values of θ using arbitrary reference angles. No absolute angle measurements are necessary. In practice it is desirable to make the measurements at values of θ as close to 180° apart as possible to reduce errors.

The equipment used for the above method can consist of a receiver in the form of two orthogonal TSL 1401 or TSL 215 linear 128xl low cost photodiode arrays made by Texas Instruments, each with a simple slit or "linear pinhole" lens with a focal length of approximately 25 mm for the TSL 401 or 50 mm for the TSL 215. Using interpolation, angles can be measured with a resolution of approximately $\pm 0.01°$ in typical indoor ambient light conditions. The LED's are high efficiency, narrow beam devices which are also used to support data communication between the transmitter and receiver to synchronise measurements and interchange data. Transmitter and receiver are each suitably mounted and protected as a unit. If there is interfering light the data communication system allows each of the units to request the other to turn its LED off intermittently so that background images can be taken which can be subtracted from the measurement images.

The angles θ_1 and $\theta 2$ are measured with an ADXL05 accelerometer (±5 milli-g) with digital temperature compensation for drift and appropriate analog and digital low pass filtering for noise reduction.

Other components employed in the measurement units include a Siemens 80C537 microcontroller of the Intel 8051 family but with built in analog to digital convertor and other on-board peripherals, keypad, liquid crystal display, serial port, AD2210 temperature sensors, infra red transceiver, buzzer, 64 kilo byte erasable programmable read only memory and 128 kilo byte paged static random access memory. Estimated total current consumption is 100-200 mA at 5 V depending on which systems are activated. The microcontroller will be programmed to effect the solving of the equations set out above.

The units can conveniently be mounted on the rims of the wheels using conventional clamps of the kind used in existing wheel alignment systems.

The system described above can be used for vehicle back and front wheels.

It will be appreciated that by appropriate programming of the microcontroller it is possible to display the calculated actual angles and show the adjustments made by a mechanic working on the vehicle wheel alignment. With the transmitter and receiver in the final positions the changes made by the mechanic to the wheel alignment parameters can be monitored and displayed and assist in the setting of these parameters to their appropriate values. It is also possible to transmit the result desired from the measurements to a hand-held controller or a remote computer or display.

Where the accuracy of the system above described requires a control against errors which may occur although the two wheels of a pair being set back one from the other this problem can be solved by measuring the "thrust angle" of the front wheels as described below and calculating the angle of the line joining the wheels with respect to the thrust angle.

"Thrust angle" is the angle between the perpendicular to the line joining the centres of the two wheels and a line parallel to the longitudinal axis of the vehicle.

This angle can be used to verify toe angles measured as described above and determine any set back of wheels, the toe and camber of which is to be determined.

Figs 3 and 4 diagramatically demonstrate the measurement of the orientation in the horizontal plane of a left rear wheel as part of the process of determining the thrust angle of the rear wheels. Two IR LED's (3) are mounted back-to-back at approximately axle height on the front wheel, with their beams propagating approximately horizontally and parallel to the side of the vehicles. Two receivers (4) similar to those used for toe and camber measurements are mounted in a single housing so that their reference axes (R and R' are 180° or a known angle apart. The housing is mounted approximately at axle height on the rear wheel such that when one receiver (4) faces forward the other faces to the rear of the vehicle. Each receiver (4) contains a single horizontally mounted TSL401 which images the LED (3) in the horizontal plane only. A measurement of the angle (A_{T1}) is taken with respect to reference axis R by the first receiver. The vehicle is rolled forward or backward so that the wheels turn through 180° or an angle such that the second receiver is aligned to measure the angle A_{T2} with respect to reference R'. If the receivers are 180° apart and axes R and R' co-linear then the absolute angle between the perpendicular to the axle of the rear wheel and the line joining the receiver and the I-ED is then given by:

$$A_T = \frac{A_{T1} + A_{T2}}{2}$$

and A_T is independent of the runout of the receivers.

The LED can be mounted on the vehicle chassis so that the angle of the wheel is measured with respect to a fixed point.

If the LED is mounted such that the line from the receiver to the LED is parallel to the longitudinal axis of the vehicle A is the toe angle of the wheel. The camber of the wheel can be similarly determined if the LED is appropriately positioned above the wheel.

If the orientations (A_L and A_R), L and R referring to left and right respectively, in the horizontal plane and toe angles (X_{tL} and X_{tR}) of a pair of wheels are determined using the above techniques then it can be shown that the thrust angle (A_p) of the pair of wheels is given by

$$A_p = (X_{tL} - X_{tR} + A_L - A_R) / 2.$$

Another possible source of minor error which can arise using the system described above can be through wheel size mismatch.

If the two wheels are of different sizes then an error (mainly in camber if $\theta_1 \approx 0$ and $\theta_1 \approx 180°$) can result as the smaller wheel rotates through a larger angle when the vehicle is moved. A similar error results if the steering is not centred - the wheel on the larger radius of curvature moves through a greater distance and hence rotates through a greater angle.

The errors in A_x (ΔA_x) and A_y (ΔA_y) can be shown to be:

$$\Delta A_x = \frac{\delta \sin \Delta\theta}{2D}$$

and

$$\Delta A_y = \frac{\delta(1-\cos \Delta\theta)}{2D}$$

where D is the trackwidth, δ the wheel diameter and $\Delta\theta$ is the difference in rotation.

For a small size mismatch ΔA_y is negligible and ΔA_x is proportional to $\Delta\theta$. This error can be detected and corrected when values of θ_1 and θ_2 for each wheel and the trackwidth and wheel diameter of the vehicle are known. The trackwidth and wheel size can be entered via the keypad or obtained from a pre-existing database in the microcontroller.

Trackwidth can be measured as follows. During measurements for toe and camber calculation a second IR LED is approximately 60 cm from the first in the X - Y plane, both LED's are imaged by the receiver and the trackwidth of the vehicle is determined by triangulation with an uncertainty of approximately ± 13 mm in 1500 mm.

An alternative approach to this problem is to measure A_x and A_y more than once. When the wheels are identical and the steering set straight ahead A_x and A_y change sinusoidally with θ. Size mismatch or steering off-centre causes one wheel to rotate further than the other and the difference in rotation $\Delta\theta$ is proportional to $(\theta_2 - \theta_1)$. Hence, when a small size mismatch is present, A_x has a sinusoidal component due to the effects of toe and camber, and a linear component due to size mismatch. Multiple measurements of A_x and θ should enable the linear component to be identified and removed, although at the expense of computational load on the measurement system.

Measurement uncertainties can arise from the use of the equipment set out above. These will generally be of no relevance as far as most road vehicles are concerned.

The alignment measurement technique described in this report has distinct advantages over conventional techniques in that the critical measurements can be made without a reference or zero value. This characteristic is achieved by performing two measurements at different wheel positions and hence cancelling the effect of runout errors.

No fixed installation or specially levelled surface is required for the operation of this system, although the surface should be reasonably flat and level.

The hardware implementation employs modern low-cost semiconductor technologies.

Limitations of the system include the requirement for enough space to roll the vehicle approximately half a wheel revolution and sensitivity to direct sunlight on the receivers.

It is envisaged that a modified (and somewhat more robust) version of this system could be mounted permanently in a pair of wheels so that toe, camber and thrust line can be measured while the vehicle is in motion. Clearly a different method for measuring θ_1 (and θ_2 such as an absolute shaft encoder or magnetic pickup) will be required for this application. It will be possible to perform the measurements only intermittently whenever the measurement heads are approximately aligned and the vehicle is travelling on a reasonably smooth surface.

This alignment technique may be useful in other applications such as alignment of rotating shafts. The simple optical angle and triangulation distance measurement techniques may find applications in other fields such as numerically controlled machines and robotics.

The above embodiment describes a determination of toe and camber angles for one wheel of a pair. In practice however the equipment will be designed so that the parameters of both wheels can be done simultaneously by measurements being taken for both wheels at the same time. Each instrument will include both a transmitter and a receiver and this will speed up the practical application of wheel alignment adjustment.

Also it will be appreciated that if parameters of a pair of wheels vary widely from the specified required values there could be inherent inaccuracies in measurements which can be avoided by the method being repeated to bring the parameters in a step-wise manner to the desired values.

The measurements required have been described above as being taken at each of two end positions before and after rotation of a wheel. Incremental rotation of the wheel giving a multiplicity of measurements may be used in practice to improve the accuracy of the calculations for the required parameters.

Those skilled in the art will understand that the method above described is confined to direct measurements of planes, angles and positions closely associated with the wheels. It

is of course possible to make measurements differently and transpose them mathematically from one frame of reference to another to give the desired results.

Further, terminology has been used in this specification which is not to be interpreted in the absolute sense. It is not possible to define mathematically exactly the variations practically acceptable from the relative location of planes, lines and points described and it will be appreciated that variations due to practical application of the theoretical determination set out in the embodiment described must be allowed for in the proper interpretation of this specification and its claims.

CLAIMS

1. A method for determining alignment parameters of one of a pair of wheels comprising selecting a first point related to a first wheel, making measurements from which the angular displacement of a plane through the first point and the axis of the first wheel to a plane through the wheel centre can be determined, selecting an equivalent second point related to the second wheel and making measurements from which the angular displacements of a line between the selected points in orthogonal planes through the first point can be calculated, rotating the wheels and related selected points through similar angles, repeating the measurements and calculating therefrom the toe and camber angles of the first wheel.

2. A method as claimed in claim 1 in which the selected points are chosen adjacent to the peripheries of the wheels and substantially parallel to the line joining the wheel centres.

3. A method as claimed in claim 2 in which the first points are selected to be below the horizontal plane of the wheel centre and the angle of rotation chosen to be greater than 180°.

4. A method as claimed in any one of the preceding claims in which similar measurements and calculations are made for the second wheel.

5. A method as claimed in claim 4 in which the measurements and calculations for both wheels are done simultaneously.

6. A method as claimed in any one of the preceding claims in which the angular displacements of the plane through the first points are θ_1 and θ_2 and the angular displacements of the line between the selected points and orthogonal planes through the first point are A_{x1} and A_{x2} and A_{y1} and A_{y2} from which $A_x = (A_{x2} - A_{x1})$ and $A_y = (A_{y1} - A_{y2})$ are determined and the angular inclination of the wheel calculated by simultaneous solution of the equations

$$X_c = \frac{A_x + X_L (\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

$$X_t = \frac{-A_y - X_c(\sin\theta_2 - \sin\theta_1)}{(\cos\theta_2 - \cos\theta_1)}$$

where X_t is the toe angle of the wheel and X_c is the camber of the wheel.

7. A method as claimed in any one of the preceding claims in which the measurements are made of the angular displacement between the selected points in orthogonal planes through the point by means of transmitted electromagnetic radiation and a receiver that records the radiation transmitted in at least one dimension.

8. A method as claimed in claim 7 in which the radiation is recorded in at least two different planes.

9. A method as claimed in claim 8 in which the radiation is visible or infra-red optical light radiation.

10. A method as claimed in claims 7 or 8 in which the different planes are orthogonally oriented to each other.

11. A method as claimed in any one of the preceding claims in which the angular displacement of the plane through the first point and the axis of the first wheel is measured by a gravitationally operated instrument.

12. A method as claimed in claim 11 in which the gravitational displacement is measured by accelerometers or inclinometers

13. A method as claimed in any one of claims 1 to 9 in which the angular displacement of the plane through the first point and the axis of the wheel is determined with respect to a non-rotating reference using position encoders or rotational displacement transducers.

14. A method as claimed in claim 6 in which errors resulting from wheel size differences or lack of centering of the steering are compensated for by determining the difference in rotation of the two wheels ($\Delta\theta$) and calculating correction to A_x and A_y by

$$\Delta A_x = \frac{\delta \sin \Delta\theta}{2D}$$

and

$$\Delta A_y = \frac{\delta(1-\cos \Delta\theta)}{2D}$$

15. A method of setting the toe-in and camber angles of a pair of vehicle wheels using the information obtained from any one of the preceding claims and mechanically adjusting the vehicle components to correct any variation of the toe-in or camber so determined from the designed angles.

16. A method as claimed in claim 15 in which the mechanical adjustments are monitored through measurements taken by the transmitter and in their final positions and visually displayed.

17. A method of determining the orientation of a wheel axis of a wheeled vehicle positioned on a supporting plane relative to a chosen plane comprising selecting a point relative to the axis of the wheel and a second point fixed relative to the vehicle and set apart from the wheel axis but in a plane approximately parallel to the plane supporting the wheels, making measurements from which the angle between the line joining the two points and a reference line can be determined, rotating the wheel through a predetermined angle,.repeating the measurements with respect to a second reference line of known variation to the first and calculating the angle of the wheel axis relative to the line joining the two points.

18. A method as claimed in claim 17 in which the toe angle is obtained by selecting the points such that the line between the points is parallel to the axis of the vehicle.

19. A method as claimed in claim 17 or 18 in which the method is applied to the other of a pair of wheels and in which the results of both sets of measurements are used to calculate the thrust angle or the set back between the pair of wheels or the toe angle of the first wheel.

20. A method as claimed in any one of claims 17 to 19 in which the measurements are obtained using electromagnetic radiation and receivers.

21. A method as claimed in claim 20 in which the radiation is light radiation from a position fixed relative to the vehicle and receivers are mounted to rotate with the wheel and are of known orientation to each other to receive the radiation from each position at which the wheel is located.

22. A method as claimed in any one of claims 17 to 21 in which the receivers are oriented at 180° to each other allowing the orientation of the wheel to be calculated from:

$$A_T = \frac{A_{T1} + A_{T2}}{2}$$

where A_T is independent of the runout of the receivers.

23. A method as claimed in any one of claims 19 to 22 in which the measurements and calculations are made for both a pair of wheels and the thrust angle (A_p) of the pair of wheels is determined from:

$$A_p = (X_{tL} - X_{tR} + A_L - A_R) / 2.$$

24. A method as claimed in any one of claims 17 to 23 used in combination with a method as claimed in any one of claims 1 to 14 to measure and verify the toe and camber angles of a wheel.

25. A method as claimed in any one of the preceding claims in which the wheel is rotated through a multiplicity of measurements made from which the required parameters are derived.

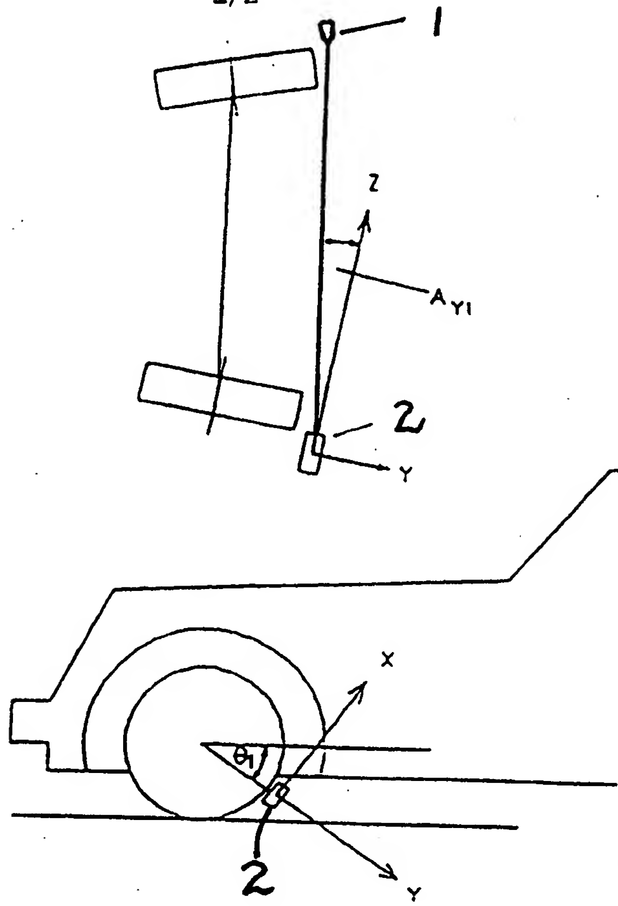

Fig. 1

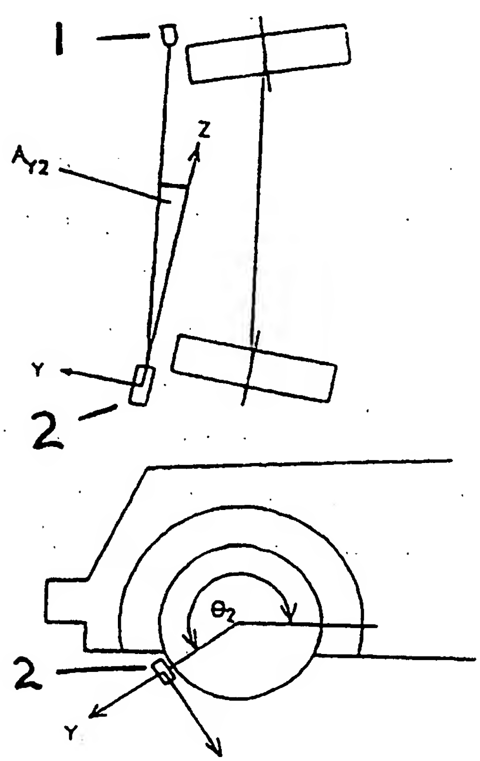

Fig. 2

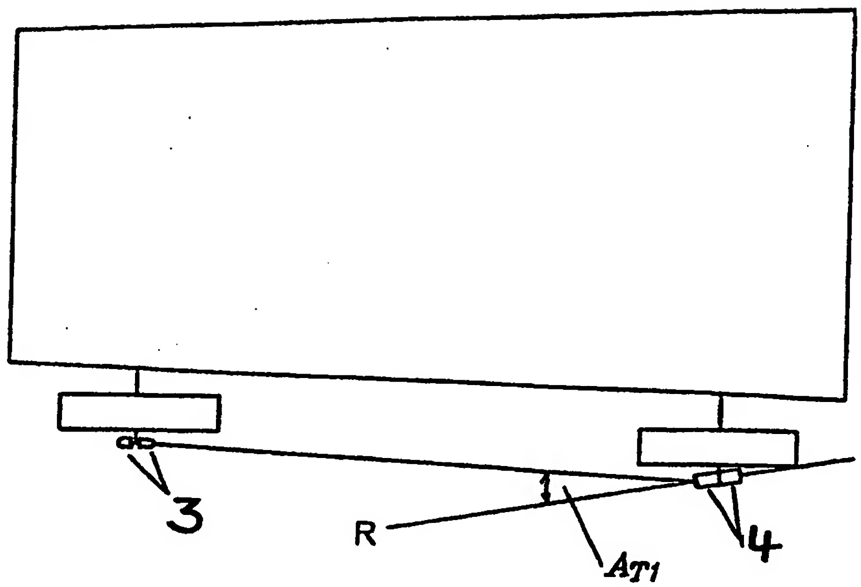

Fig. 3

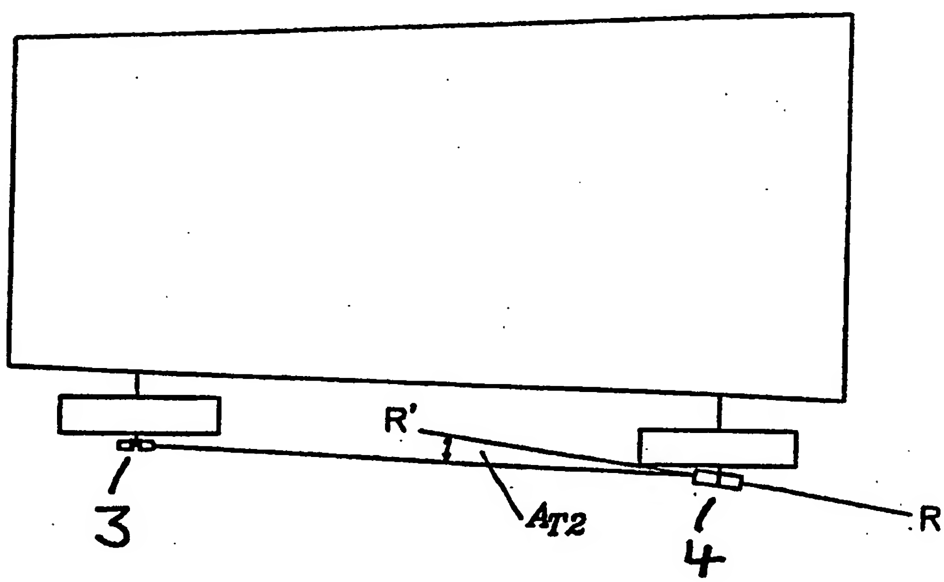

Fig. 4

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00831

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: G01B 11/275, 21/26, 121:14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G01B 11/275, 21/26, 121:14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT and JAPIO : rotat:

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2291976, A, (Anzen Motor Car Co. Ltd), 7 February 1996 page 18, figs 3-5	17
A	WO 88/06269, A, (Merrill Engineering Laboratories Inc.), 25 August 1988 abstract	17
A	GB 2258315, A, (V.L. Churchill Ltd.) 3 February 1993	1

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
23 January 1998

Date of mailing of the international search report
06 FEB 1998

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INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 97/00831

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5018853, A (Hechel et al.) 28 May 1991	1
A	FR 1152877,A (M. Lucien-Robert Marteil) 26 February 1958	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No.
PCT/AU 97/00831

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	2291976	CA JP	2154711 8043262	DE	19527809	FR	2723198
WO	88/06269	EP	348420	GB	2223321	US	4856199
GB	2258315	US	5243766				
US	5018853	AU JP	77350/91 7103738	CA	2043079	EP	460470

END OF ANNEX